COGNITIVE BEHAVIOR AND INFORMATION PROCESSING UNDER CONDITIONS OF UNCERTAINTY

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Over the past decade, research and synthesis of findings on decision making have led to the unequivocal conclusion that earlier conceptualizations about the decision process were either overly simplistic or lacking in veridicality. The nature of the decision task, and the conditions under which it is performed have a profound influence on the decision process. These effects include the decision maker's view of the process, and (probably) information processing strategies which the decision maker may be unaware of having chosen. Further, there is a growing body of literature which suggests that the nature of the decision process is strongly influenced by the organizational level at which the decision maker is located, i.e., what his critical functions in the organization are, and the nature of the cognitive skills he therefore must bring to the task. The purpose of the present paper is to present some of these data, together with some possible implications they have for decision making under conditions of uncertainty, and for risk management.

These latter considerations will have particular relevance for program managers, for the following reasons. If we assume that program managers are differentially effective, then it is reasonable to assume that part of the variance in effectiveness is <u>ad hominum</u> and part is environmentally determined. To some extent, <u>ad hominum</u> variance can be controlled through individual assessment and selection, though this is an expensive venture. However, environmental engineering offers much more promise. It seems highly likely that environments can be made more adaptive for effective decision performance with relatively little cost to organizations. If this is a correct assumption, then interesting new approaches to improving decision performance under conditions of uncertainty will become available.

First, the following definitions of risk and uncertainty seem useful (Lopes, 1983):

- Risk defines the condition under which the possible outcomes of a decision are known, and so are the probabilities attached to each.
- Uncertainty defines the condition under which the outcomes are known but the probabilities are not. (Further, there may be conditions of extreme uncertainty under which not all the outcomes are either knowable, or anticipated if knowable.)

The essence of this distinction is between a condition of rationality or one of, at best, bounded rationality. The problem is that a substantial amount of the early work on decision making, and many of the early conceptualizations, addressed risk to a far greater extent than uncertainty, as thus defined. However, most of the decision making done by humans at senior levels of responsibility, either program managers or executives, is not done under conditions of risk, as defined, but rather under conditions of uncertainty.

Three useful reviews of the decision literature have appeared during the past six years (Slovic, Fischoff, and Lichtenstein, 1977; Einhorn and Hogarth, 1981; Payne 1982). In the first of these, Slovic, Fischoff, and Lichtenstein included a substantial treatment of decision aiding, but at the same time noted some emerging general findings that challenge rational decision theories, i.e., those which have as a basic assumption maximization of expected value (EV), expected utility (EU), or subjective expected utility (SEU). First, information load consistently has shown strong impact on information acquisition utilization strategies. Second, strategies for search and evaluation may vary from one stage of a decision problem to another, a finding which repeatedly occurs and which confounds rationality assumptions. Payne's review adds a third general finding: decision makers seem to have some kinds of learned rules which are probably context bound and generalized across situations (that is, they are ways of dealing with decision requirements) whether it is appropriate to generalize them or not. Payne noted that Abelson's scripts and Pitz's production systems are good examples.

The second of the three reviews cited earlier had a broader objective:

> "...to place behavioral decision theory in a broader perspective, emphasizing importance of attention, memory, cognitive representation, conflict, learning, and feedback."

As does Payne, Einhorn and Hogarth challenge normative models:

> "Judgement and choice are strongly influenced by seemingly minor changes in task and context. And information search and evaluation strategies are interdependent. A variety of strategies exists, and little is known about criteria for rule taking, rule shifting, and the choice of evaluation strategy."

Uncertainty arises from the environment, from equivocal cue-criterion relationships, inconsistentcy in individual information combination strategies, and the question of how cues should be weighted in relation to their predicitiveness. Finally, they note that there is limited learning capacity in humans, and that humans paradoxically show learned confidence in judgement despite obvious low validity of judgement.

While human decision performance even in simple conditions is subject to characteristic biases and errors, a good case can be made that performance becomes worse as task complexity increases. Payne (1982) focuses on the impact of task complexity, noting that as complexity increases, information load presumably also increases, and several predictable impacts reliably are found:

- Compensatory strategies shift to conjunctive or elimination-by-aspects strategies.
- Response variability increases and choice quality decreases.
- Decision makers rely more on negative information to reduce complexity (with increases in time pressure).
- Risk propensity is reduced by a more constrained time horizon.
- Decision makers tend more strongly not to transform information but rather to use it in the form conveyed, which reduces cognitive strain but does little to enhance quality of decisions.

In addition, decision makers are systematic in violation of some rationality assumptions, but nonsystematic in violation of others. For example, there is apparently systematic tendency to be <u>risk aversive</u> for gain and <u>risk seeking</u> for losses. However, Lopes (1983) seeks to explain this systematic violation of rationality assumptions in terms of psychological variables such as the decision maker's status and long term goals, which of necessity are idiosyncratic. Payne makes a similar point, that decision makers operate in terms of a psychologically relevant outcome space (problem space) which may or may not conform either to reality or to the outcome space of other decision makers.

Finally, Payne notes that little is known about how decision strategies are learned. Heuristics are widely used, and the evidence suggests that they are context dependent. However, once learned, they can be very enduring. A great deal more needs to be learned about how they are acquired, and how feedback processes operate to mediate their retention over time.

As was noted by Payne, Braunstein and Carroll (1978), decision research to date has focused more on outcomes than on processes. In order to understand decision performance better, we need better data on how decision makers acquire and use information, the information that eventually is used, and the conditions under which it is used. If decision making is viewed more from the perspective of information processing behavior, focusing on search/acquisition, evaluation, and feedback/learning, avenues may well be found to improve decision performance through attention to environmental and individual factors that influence these processes. The remainder of this review will focus on these issues. Three broad categories will be addressed: (a) the information processing characteristics of the human decision maker, (b) the nature of the function served by decisions within the organizational context, and (c) the form taken by the requisite information in relation to the decision function served and the cognitive skills of the decision maker.

Broadbent, among many others, has contributed substantially to an understanding of the characteristics of human decision makers in terms of the basic processes involved. In a seminal article, he (Broadbent, 1977) described research on control systems which mediate throughout processes in human information processing. Processing tasks were defined in two ways:

- Closed tasks - open-chain sequences which require no check with the environment for execution.
- Open tasks - unpredictable sequences of actions in relation to unpredictable series of events, which requires continuing check with environment.

In a series of experiments, Broadbent demonstrated that human information processing occurs at least at two levels, and that these levels may correspond to the type of tasks performed. One control system operates in an open chain fashion, accepting input and producing output, without any feedback loops. A second control system can be visualized as an integrating, feedback operated processor, with a capacity for both rewriting the rules used by the open chain processor, and for providing it with inputs. Broadbent visualized these as "lower" level and "upper" level, respectively. A key assertion is that lower level processes can operate in parallel, as long as they do not require the same input sensory modality, but that upper level processes cannot. Perhaps of even greater interest, he theorized that control of the total information processing task shifts from one level to another, depending on context, task, and feedback.

Awareness of differential processes such as these is not reflected in the methodology reported in much of the current literature. Many findings are based on laboratory tasks which probably elicit use of lower level processors, while others are based on tasks requiring upper level processors. Specifically, repeated

responding in a simple lottery could conceivably be accomplished by a lower level processor. In such tasks, it would not be surprising to find the use of quite different search/acquisition and evaluation strategies in those which activate upper level processors. Further, it would not be surprising to find that the switching control system levels is contingent on such variables as information load, with upper level systems operating under conditions permitting the longer processing times probably required, and switching processing to lower level systems when available processing times are inadequate for the functioning of upper level systems. More research correlating control systems with tasks by conditions is needed for developing understanding of human information processing characteristics of the nature of decision tasks.

In preparation of this review, no research was found on information processing requirements for program managers. However, there is a growing body of knowledge about decision and information processing behavior of senior executives. If it can be assumed that similar behaviors are required of senior executives and managers of complex programs, conclusions can be drawn from analysis of that literature.

Two interesting recent publications are relevant (Kotter, 1982; Draft and Lengle, 1983). The first is one of a growing number of works in which the on-the-job behavior of senior managers is reported and analyzed. The second is an analysis of the information-processing task of the senior executive. In it, the authors assert that the managerial task is to make sense out of complex decision making - and it can be argued that this is a central part of complex decision making - and to coordinate internal activities within the organization. They then advance the concept of information richness, which is defined as the information carrying capacity of data.

- Situations of greater uncertainty (equivocality) require data of greater richness, and
- Media can be scaled in terms of their richness into five categories from most to least rich: face-to-face, telephone, letter, memorandum and computer printout. (Scaling is accomplished through use of the variables of channels utilized, feedback capability, source and language used.)

In essence, simple phenomena can be managed with simple rules, and with information of low richness; complex phenomena require rich information, and probably yield more easily, in general, to the use of heuristics than to more mechanical computational procedures. But Kotter showed convincingly that the phenomena of concern to senior executives in his sample were indeed complex. He further provides evidence concerning their sources of information that strongly supports the Draft and Lengel hypotheses. Senior executives obtain most of their information from "rich" sources. Similar support is contained in Mintzberg's (1973) observational data on the job of the senior manager. Senior managers make little use of low richness sources, and the extent to which they do so decreases with increases in uncertainty. Not only are their most critical tasks focused on fuzzy problems, but also some of the relevant data are essentially political (Brightman, 1978). Draft and Lengle concluded:

- The best form for an organization to take is one which addresses its information processing needs best.
- Management information systems designers lack a coherent theory of manager needs and manager behavior.

To this might be added the need for decision making models relevant to executive function under such conditions, and the unique information processing skills of good decision makers.

Streufert (1970, 1981) addresses these skills from a cognitive complexity perspective in research dealing with information search and the impact of load stress in complex decision making. His research shows that decision makers at senior levels perform better if they engage in cognitive processes of differentiation and integration of their information dimensions, and then use these dimensions in their subsequent decisions. As expected, work pressure/laod reduces the capacity to do this. However, individuals who characteristically do more differentiation and integration under light loads are less impacted by load increases. Further, predispositions to multidimensionality are trainable, though with difficulty, perhaps paralleling Payne's observation about problems in the learning of decision strategies. As a final point, Struefert notes another finding paralleling decision research findings on feedback acquisition and use. In his experiments, he found that the amount of information needed to change a decision exceeded that needed to make one. One might therefore conclude that unidimensional information processors will not discover bad decisions as effectively as do multidimensionals. If a correct inference, cognitive complexity then relates to search/acquisition and evaluation in complex tasks, though of necessity it would not in simple tasks not requiring cognitive complexity.

Thus far, select findings on the characteristics of human decision makers and the relation of cognitive skills to information requirements and decision outcomes have been presented. A final issue is the time horizon (perspective) of the decision maker. Jaques (1976) has developed a theory of organizational structure which identifies levels of performance requirements and relates them both to the time frames

within which action must be planned by level. For practical purposes, seven levels are defined, as shown in Figure One. They can be broken into three more general sets, strategic, general management, and operational execution. If these levels are cross-matrixed with Streufert's cognitive complexity categories, and if successively more complex program development and management activities are located logically within the matrix, the cell entries shown in Figure One emerge. These, of course, are only theoretical. However, if the theory is accurate, there are several strong implications. First, the information processing requirements of successively higher levels of organization (and management of successively more complex programs) should increase in volume and complexity. A diagonal from lower left to upper right in the matrix coincides with the direction of increasing information load. Second, if Jaques is correct about the critical functions of incumbents by level, the degree of concreteness of required information and the form it should take change from level to level. More complex problem situations, as shown on Figure One, require the use of more abstract information, i.e., consolidated rather than individual elements, transformed to show trends as opposed to sums, second derivatives rather than first derivatives, and so on. Finally, executives and program managers at the more senior levels should have longer time horizons than shorter, and should have demonstrated capacity for multidimensional integration information processing skills.

The research base thus far available is not large, and very substantial effort is now being applied to the creation of executive development technology, using the logic of the above. Findings from this research will enable substantially more confidence in the drawing of conclusions than now is possible. However, it seems clear that some improvements in organizational performance (and probably program management) can be achieved. One fruitful direction is assessment of potential executives and program managers. If cognitive complexity and the capacity for functioning over extended time periods (10-20 years) are requirements at the most senior levels, assessment programs to permit early identification and development of talent would seem to be a good investment. Training and development activities could then be purposefully tailored to permit career management against known executive skill performance requirements. A second fruitful approach is engineering of the information environment. Given that load decreases decision quality and limits the multidimensionality of senior executive performance, organizationally imposed information loads, to the extent they exceed optimum levels, impact on organizational performance. However, in bureaucracies, there frequently is little filtering of the content of imposed loads in relation to organizational priorities. Further, rules proliferate in bureacuracies, and performance is audited by a variety of "seniors" to include one's formal boss. However, the perspectives of the "audit" frequently vary from one auditor to another, and in some cases do not directly reflect awareness of organizational priorities and the requirements for effective organizational performance. In terms of level of performance, an axiom might be that the greater the number of rules, the less integration the incumbent can show, and the lower the quality of decision outcomes will be, outside some boundary condition. Another might be that the greater the load, e.g., through imposition of performance requirements established by an organizational rule-making subsystem (such as personnel), the lower will be the integrative quality of decision outcomes. Finally, organizational structure probably influences decision quality outcomes. For complex decision making and the processing of information under conditions of substantial uncertainty, mechanistic organizations (like bureaucracies) probably impose upper limits on the quality of executive (and program manager) performance.

If these inferences are correct, progress toward higher quality decisions and higher organizational performance probably can be realized through selection and development of early talent; systematic review of rules and procedures to ensure simplicity and consistency in complex environments (in simple environments it does not matter); systematic auditing of the information loads imposed on critically important senior executives and program managers to ensure they are not burdened by requirements generated by suboptimizing subelements; and tailoring of organizational structure to match the complexity and time frame of the level of performance required.

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FIGURE 1

COGNITIVE COMPLEXITY AND TIME HORIZON

	COMPLEXITY		
CAPACITY	UNDIMENSIONAL	MULTIDIMENSIONAL	
		DIFFERENTIATOR	INTEGRATOR
STRATEGIC VII (20 Years +) VI (20 Years)		Cross Program Tradeoff Analysis -- Investment Strategy Determination	Future Force Concept Development
OPERATIONAL MANAGEMENT V (10 Years) IV (5 Years) III (2 Years)	SINGLE PROGRAM MANAGEMENT	MULTIPLE PROGRAM MANAGEMENT - ANALYTIC	MULTIPLE PROGRAM MANAGEMENT -- CROSS PROGRAM INTEGRATION
OPERATIONAL EXECUTION II (1 Year) I (0-3 Mo)	PROGRAM ELEMENT ADMINISTRATION	PROGRAM ADMINISTRATION	MULTIPLE PROGRAM COORDINATION